RESEARCH DEPARTMENT

Subjective assessments of the portrayal of motion produced by simulations of field-store standards conversion

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R.E. Davies, M.A.
S.J. Lent, A.M.I.E.R.E.
M.T.A. Salter, Grad.I.E.R.E.

D. Maurice

for Head of Research Department

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SUMMARY

It is shown that the process of television standards conversion involving a change of field frequency degrades the portrayal of movement in the scene by introducing a jerky motion to certain types of movement.

Experiments are described which show that in order to provide satisfactory portrayal of motion, when converting television standards from 60 fields per second to 50 fields per second and vice versa, it will be very desirable to incorporate a form of movement interpolation in the standards converter.

1. INTRODUCTION

In television standards conversion involving a change in the number of fields per second, it is necessary to omit picture information when converting from a higher to a lower field rate and to repeat some information when converting from a lower to a higher field rate. This process degrades the portrayal of movement in the scene.

Several types of field-store standards converter have been proposed. In general, they operate by subjecting the input signal to a cyclically varying delay. When converting from a higher to a lower number of fields per second the delay is gradually increased throughout several input field periods and suddenly reduced to zero; when converting from a lower to a higher number of fields per second the delay is gradually reduced throughout several input field periods and suddenly increased to a maximum. The sudden change in the delay coincides with either the omission or duplication of an input field. This omission or duplication of an input field can impart a jerky appearance to movement in the scene which appears quite smooth and normal in the input picture. It has been suggested that this effect of field-store standards conversion may be ameliorated by means of "movement interpolation", in which a moving object is portrayed in the output picture sometimes as one image and sometimes as two or more images derived from successive input fields, but it is likely that such measures would add significantly to the cost of a field-store standards converter. This report describes experiments to assess the degree of picture impairment due to jerky movement portrayal that would ensue from using a field-store standards converter of the simpler type in which movement interpolation was not incorporated.

2. GENERAL

The position of a point on an object moving with constant velocity may be described by means of two time-dependent position co-ordinates:

$$(x_0 + \alpha t,\ y_0 + \beta t)$$

where (x_0, y_0) is its position at time 0, t is the time variable, and α and β are its velocities in the two co-ordinate directions. The camera observes the object at discrete instants once per field in order to produce the normal signal waveform. After conversion, the image is displayed at other discrete instants, once per field, in the positions at which it was observed by the camera. Due to the varying delay to which the signal is subjected during conversion, the actual position of the object in the scene is different from the position at which it is displayed by an amount $(\alpha T, \beta T)$, where T is the delay to which the signal has been subjected. For field-store conversions between the U.S. standard of 525 lines, 60 fields per second and the European standard of 625 lines, 50 fields per second, the delay T is cyclic within a 1/10th second interval and has a sawtooth form with a maximum duration of one input field period. Thus the positional error can be deduced from the velocity of motion of the object. If the object moves at constant velocity, its motion will appear to jerk at a rate of 10 c.p.s. in its direction of motion. For example, if an object televised at the 60 fields-per-second standard were to move horizontally at a rate of five picture elements per field (a rapid movement equivalent to complete traverse of the raster in about 1½ seconds), its position as displayed at 60 fields per second, during a sequence of fields, would correspond to shifts of 0, 5, 10, 15, 20, 25, 30, 35, etc. picture

elements from its initial position. After conversion to the 50 c/s standard its position on successive fields would be 0, 5, 10, 15, 20, 30, 35, etc. picture elements from its initial position; due to the omission of every sixth field it would never appear at the position corresponding to a shift of 25 picture elements. If the same moving object had been televised at 50 fields per second, its position as displayed at 50 fields per second would have followed the shift sequence 0, 6, 12, 18, 24, 30, 36, etc. picture elements. Thus the error in position introduced by the conversion process would follow the sequence 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, etc. picture elements. Thus there would be an apparent movement jerk with a maximum value of four picture elements superimposed on the motion of the object; this jerk would repeat every five fields of the 50 c/s standard, i.e. at a rate of 10 c/s.

In order to assess the picture impairments produced by this movement jerk, two series of experiments have been carried out. The first series was designed to determine the relationship between, on the one hand, the impairment of the portrayal of moving subject-matter due to field-store standards conversion without movement interpolation and, on the other hand, the effective velocity of a scene that moved bodily (i.e. the speed of camera "panning"). These experiments were carried out by simulating, by means of a suitably modified flying-spot slide scanner, the pictures resulting after field-store standards conversion without movement interpolation from the 525 line, 60 field per second standard to the 625 line, 50 field per second standard.

In the second series of experiments, the effects of field-store standards conversion without movement interpolation upon movement portrayal were simulated using typical moving subject-matter; in this case the simulations were performed by means of motion-picture film. Pictures obtained in this way were compared with others of the same subject-matter displayed at a field rate equal to that used by the camera (i.e. pictures simulating those obtainable before conversion). Standards conversions both from 525 lines, 60 fields per second to 625 lines, 50 fields per second and vice versa were simulated.

3. THE RELATIONSHIP BETWEEN PICTURE IMPAIRMENT AND CAMERA PANNING SPEED

3.1. Experimental Arrangements

As mentioned in Section 2, signals simulating those that would be obtained after field-store standards conversion from 525 lines, 60 fields per second to 625 lines, 50 fields per second, were derived from a suitably modified flying-spot slide scanner. Three principal modifications were involved. First the size of the raster on the flying-spot scanning tube was reduced so that the slide was scanned only over half its height and half its width. Secondly, the raster was made to move across the screen of the scanning tube at various low constant speeds by means of suitably slowly-varying currents passed through the line-shift coils; this resulted in displayed pictures similar to those produced by a camera panning across a stationary scene. Finally, a small perturbing current was also passed through the line-shift coils in order to displace the scanning raster according to the sequence of position errors which would be introduced by field-store standards conversion and which would result in movement jerk in the displayed output picture.

In order to ensure a valid simulation, the magnitude of the perturbing current causing movement jerk was related to the rate of change of the slowly-varying current introduced into the line-shift coils in order to simulate camera panning. The perturbing-current waveform consisted of a sawtooth with a period of 1/10th of a second. Fig. 1 shows the composite waveform applied to the line-shift coils together with the waveforms of the slowly-varying current and the perturbing current from which it was formed.

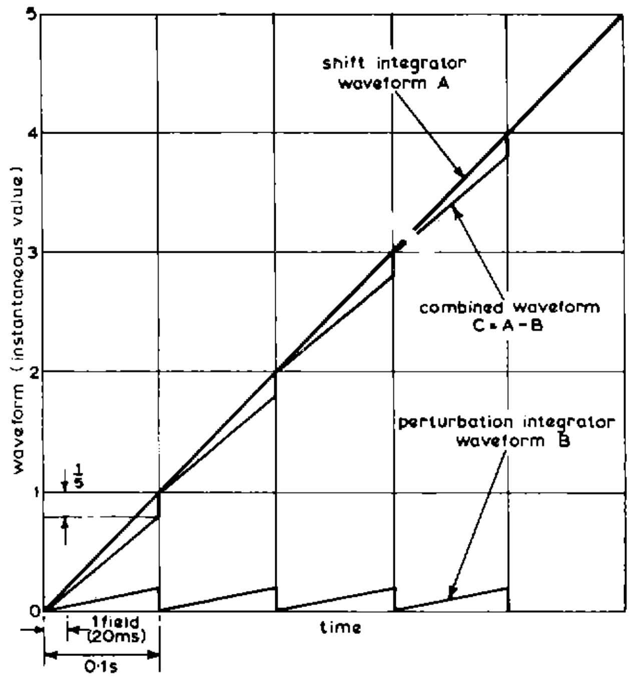

Fig. 1 - Diagram of waveforms used to form the perturbation current for the line-shift coils

Ten observers, seated at six times picture height from a 21 in. monitor, were shown the effects of the simulated field-store standards conversion on a scene of houses and trees which contained a considerable amount of fine detail. A variety of panning speeds were simulated by using various values of mean shift-velocity and subjective tests were

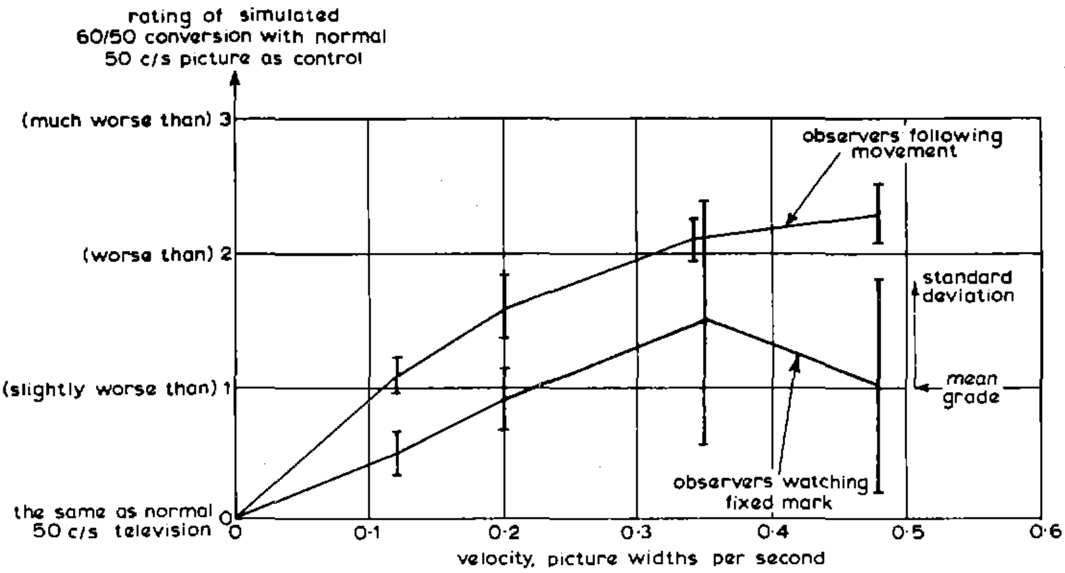

Fig. 2 - Subjective comparison of the movement portrayed of a standards converted picture with a normal television picture

carried out under two sets of conditions. In a first set of tests the observers were asked to follow the movement in the scene and to grade the impairment due to the movement jerk, and in a second set of tests they were asked to concentrate their attention upon a fixed mark attached to the screen of the display tube and to grade the impairment of the portrayal of the scene as it appeared to sweep past the fixed mark. In order to permit the observers to assess the impairment due to movement jerk, the observers were presented, in each test, with pictures derived either with or without the use of the perturbing-signal waveform. When the perturbing signal was absent the pictures could be regarded as being derived from a panned camera and displayed prior to field-store standards conversion. When the perturbing waveform was used, this simulated the introduction of field-store standards conversion into the signal chain.

In the tests the observers were not informed which picture had been derived using the perturbing waveform; they were shown pictures labelled either A or B. Sometimes condition A represented the use of the perturbing waveform and at other times condition B represented this condition; the choice was made at random by the experimenter. The observers were asked to grade their opinions of the quality of movement portrayal by means of the comparison scale given below:

-3 A much worse than B

-2 A worse than B

-1 A slightly worse than B

0 A the same as B

1 A slightly better than B

2 A better than B

3 A much better than B

3.2. Results

Fig. 2 shows the relationship between comparative subjective grade and the velocity of panning given in terms of picture-widths per second, i.e. if an object moved right across the screen in 10 seconds, the velocity was 0·1 picture-widths per second. The measure of agreement among the observers is indicated by the values of standard deviation. It is seen that agreement was good when the observers were following the movement in the scene; however, there were appreciable differences of opinion concerning the comparisons for the faster panning speeds when the observers were watching the fixed mark.

In no case did any observer vote the perturbed picture (i.e. the picture showing the effect of simulated standards conversion) better than the unperturbed picture (i.e. the unconverted picture) even for the slowest panning speeds simulated. Further, it would appear that movement judder was less visible when the observer was concentrating on the fixed mark on the screen; this is a common condition in practice where the camera is panned to follow a moving object and the background moves with respect to the camera.

4. ASSESSMENTS OF PICTURE IMPAIRMENT USING TYPICAL SCENES

4.1. *Experimental Arrangements*

In order to simulate standards conversion from 50 fields per second to 60 fields per second, a motion-picture negative film was exposed at the

rate of 50 frames per second and a positive film produced from the negative by step-printing in which every fifth frame was duplicated; this film could then be projected at a rate of 60 frames per second. Conversely, in order to simulate a conversion from 60 fields per second to 50 fields per second a negative was exposed at 60 frames per second and the corresponding positive produced by step-printing in which every sixth frame was omitted; this film could then be projected at 50 frames per second. In these simulation experiments using film, four different sequences were used, each sequence showing a different type of movement and lasting a few minutes. The subject-matter of the four sequences was:

Sequence (a) : Fast-moving traffic

Sequence (b) : A schoolboys' cricket match

Sequence (c) : Railways trains moving at medium speeds

Sequence (d) : A lecturer indicating various points on a blackboard diagram by means of a pointer

Each sequence was photographed using, simulteneously, two side-by-side 16 mm cameras running respectively at approximately 50 frames per second and at approximately 60 frames per second. In both cases each frame of film was exposed for the minimum time required to give adequate exposure of the film, thus minimizing movement blur. Normal positive films were made from the two negatives in addition to the step-printed versions required for standards-conversion simulation. Thus, four versions of each of the four sequences photographed were available as prints. Editing was then carried out so as to produce a composite film in which all four versions of each sequence were grouped together. In this way, it was possible to view, in rapid succession, four versions of a particular sequence obtained in four different ways. Thus, one particular sequence could be viewed as a result of:

(i) Photography at 50 frames per second, projection at 50 frames per second

(Simulated 50 field television).

(ii) Photography at 60 frames per second, projection at 50 frames per second

(Simulated standards conversion, 60 to 50 fields).

(iii) Photography at 60 frames per second, projection at 60 frames per second

(Simulated 60 field television).

(iv) Photography at 50 frames per second, projection at 60 frames per second

(Simulated standards conversion, 50 to 60 fields).

The composite film was shown by means of back projection on to a screen arranged so as to simulate the masked face-plate of a 21 in. cathode-ray tube; the screen was mounted in a large dividing partition between the projector and the observers, who were seated at a distance of six times picture height in front of the screen.

In order to permit the film to be projected at the appropriate speeds a 16 mm Bell and Howell projector normally intended to operate at 24 frames per second was adapted so as to operate at either 50 or 60 frames per second; this involved considerable modifications to the claw mechanism and the rotating shutter, together with provision of an auxilliary drive-motor necessary for the higher frame speeds.

In the subjective tests, the observers were shown in turn all four versions of each of the four sequences; however, the four versions of any one sequence were presented in a random order which was different for each sequence. The observers were asked to study carefully the portrayal of movement and to grade the impairment of the movement portrayal, as shown in each of the four versions of each sequence, in terms of the impairment scale given below:

1. Imperceptible
2. Just perceptible
3. Definitely perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

The observers were not asked to regard the versions produced at 50 and 60 frames per second representing normal television as "controls" against which the standards conversion representations were to be compared; on the contrary, they were asked to assess the normal television representations in precisely the same way as the representations of standards conversion.

4.2. Results

The two sets of results shown in Table 1 were obtained using technical and non-technical observers who viewed all four versions of each of the four sequences. It is seen from the gradings given by both groups of observers that the degradation of movement produced by simulated conversion from 50 to 60 fields per second depended largely on the subject-matter and nature of the movement in the scene. Smooth movement, typical of fast-moving traffic and trains, was considerably impaired whereas the type of movement produced by the cricketers and the lecturer suffered hardly any impairment.

TABLE 1

PORTRAYAL OF MOTION

15 technical observers
15 non-technical observers

SCENE	PHOTOGRAPHED AND DISPLAYED AT 50 FRAMES PER SECOND		PHOTOGRAPHED AND DISPLAYED AT 60 FRAMES PER SECOND		PHOTOGRAPHED AT 50 FRAMES PER SECOND AND DISPLAYED AT 60 FRAMES PER SECOND		PHOTOGRAPHED AT 60 FRAMES PER SECOND AND DISPLAYED AT 50 FRAMES PER SECOND	
	TECHNICAL	NON TECHNICAL	TECHNICAL	NON TECHNICAL	TECHNICAL	NON TECHNICAL	TECHNICAL	NON TECHNICAL
	MEAN GRADE	MEAN GRADE	MEAN GRADE	MEAN GRADE	MEAN GRADE	MEAN GRADE	MEAN GRADE	MEAN GRADE
Traffic	1·25	1·58	1·20	1·25	3·96	3·3	5·02	3·96
Cricket	1·25	1·52	1·45	2·00	2·11	1·92	4·09	2·77
Trains	1·19	1·65	1·06	1·58	4·82	4·09	5·02	4·62
Lecturer	1·20	2·00	1·26	1·78	2·31	1·58	4·09	3·43
Mean grade	1·24	1·70	1·25	1·67	3·34	2·76	4·61	3·74
Mean grade All observers	1·47		1·46		3·05		4·18	

IMPAIRMENT SCALE A

1. Imperceptible
2. Just perceptible
3. Definitely perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

For simulated conversion from 60 to 50 fields per second all types of movement in the sequences used were badly degraded and the portrayal of motion was generally rated at least one subjective grade worse than the corresponding simulated 50 to 60 field per second conversion. The reason for this is no doubt due, in the former case, to the omission of information which causes a jump in the position of a moving image larger than that experienced with normal presentation. However, in the latter case, information is repeated which causes the movement of an image to be momentarily arrested, but there is no increase in the positional jump of the image.

A further test, carried out as before but with the projection speeds exchanged for the composite film simulating standards conversion, showed that the 60 to 50 field per second simulated conversions, when projected at 60 frames per second, produced no significant changes in the mean subjective gradings; however, when the 50 to 60 field per second simulated conversions were projected at 50 frames per second they suffered an increased impairment of almost one subjective grade. This was probably caused by the unnaturally slow movement reproduced and the longer period during which movement was arrested.

A further analysis of the results is given in Table 2 and shows the percentages of observers assessing the portrayal of movement worse than grade 3. Although the non-technical observers appeared to be more tolerant in their assessments of movement portrayal, more than three-quarters of all observers gave an assessment worse than grade 3 for simulated conversions from 60 to 50 fields per second, whereas less than half of all the observers found the impairment of the movement portrayal, in conversions from 50 to 60 fields per second, to be worse than grade 3.

TABLE 2

PORTRAYAL OF MOTION

Percentage of observers' assessments in Grades 4, 5 and 6

OBSERVERS	SIMULATED CONVERSION FROM 50 TO 60 FIELDS PER SECOND	SIMULATED CONVERSION FROM 60 TO 50 FIELDS PER SECOND
Technical	50%	92%
Non-technical	30%	62%
All	40%	77%

It is interesting to note from Table 1 that, despite the increased amount of information presented with respect to the positions of moving images, the observers did not appear to show any preference for the normally produced versions of the sequence photographed and shown at 60 frames per second as compared with the same sequences photographed and shown at 50 frames per second.

5. CONCLUSIONS

The results of the first series of experiments; viz., those that used a slide scanner, show that with all but the slowest camera panning speeds, movement judder resulting from conversion from 60 fields per second to 50 fields per second without movement interpolation will be visible and will degrade the picture significantly. The picture impairment will be greatest when the panning speed is high and the viewer is following the background as it moves across the screen, but will be less when the viewer concentrates on the moving object which the camera pan is intended to follow. In general, the judder caused by the conversion process is visible at camera panning speeds greater than one tenth of the screen width per second; assuming 500 picture elements per active line, this speed corresponds to a displacement of 50 picture elements per second or one picture element per field period.

The results of the second series of experiments, viz., those that used motion picture film, show that the majority of viewers would find the portrayal of most types of motion to be unsatisfactory when converting from 60 fields per second to 50 fields per second without using movement interpolation. The portrayal of motion achieved when converting from 50 to 60 fields per second, without the use of movement interpolation, is likely to be generally acceptable by the majority of viewers although for some types of scene movement, the effect could be objectionable.

The general conclusion to be drawn from both series of experiments is that in order to provide a standards converter suitable for conversion from 60 fields per second to 50 fields per second and vice versa, it will be very desirable to incorporate, in the standards converter, some suitable form of movement interpolation.

6. REFERENCE

1. "A field-store converter using ultrasonic delays as the storage medium", BBC Research Report No. T-136, Serial No. 1964/65.

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